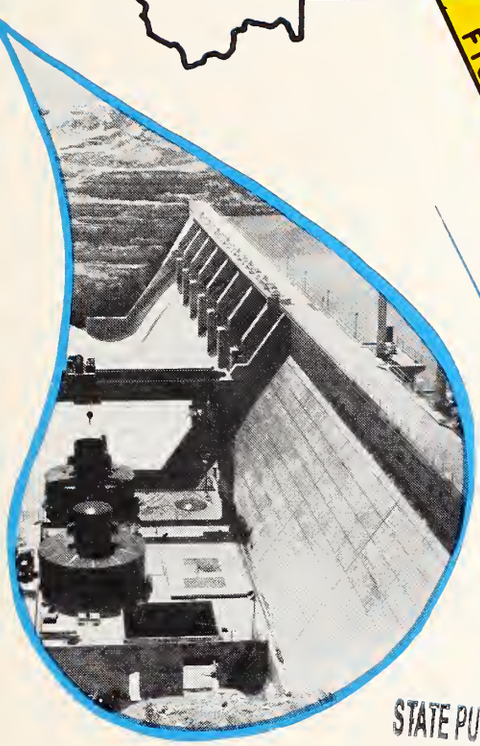
333.91
W291I4

Montana Water Resources Board

INVENTORY SERIES NO. 4



FISH & WILDLIFE
INDUSTRY
IRRIGATION
MUNICIPAL
POWER
RECREATION

Water Resources and Planning

1968

STATE PUBLICATIONS COLLECTION

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

Montana State Library
3 0864 1006 8366 6

STATE OF MONTANA
MONTANA WATER RESOURCES BOARD
SAM W. MITCHELL BUILDING
HELENA, MONTANA

"A Comprehensive Water and Related Land Resources Plan for the State of Montana"

INVENTORY SERIES REPORT NO. 4

MONTANA WATER RESOURCES AND PLANNING

OCTOBER, 1968

The work upan which this repart is based was supparted primarily by funds pravided by the Mantana Legislature and with funds furnished by the Water Resaurces Cauncil under Title III af the Water Resaurces Planning Act af 1965 (Public Law 89-80).

3 REPORTER PRTG. & SUPPLY CO.

Tongue River Dam and Reservoir—a Water Resources Board project.

FOREWORD

This publication, "Montana Water Resources and Planning" was prepared by the Montana Water Resources Board. It contains general information on Montana's water together with a proposed framework in which to plan for its optimum future use.

This booklet is the fourth item in a statewide water planning series which the Board is publishing with funds provided by both Montana's 1967 Legislature and the Federal Water Resources Council under Public Law 89-80.

The Montana Water Resources Board wishes to express appreciation to the following organizations who made available to the Board some of the photographs, charts, and/or maps contained in this booklet:

Montana Highway Commission, Montana Power Company, State Advertising Department, State Department of Planning and Economic Development, State Fish and Game Department, U. S. Bureau of Reclamation, U. S. Geological Survey, U. S. Weather Bureau, and Waldorf-Hoerner Paper Products Company.

Everett V. Darlinton
Director
Montana Water Resources Board

Digitized by the Internet Archive
in 2016

https://archive.org/details/montanawaterreso1968mont

MONTANA WATER RESOURCES AND PLANNING

CONTENTS

I. INTRODUCTION 1

II. MONTANA'S WATER RESOURCES

A. Precipitation 3
B. Surface Water 4
C. Soil Moisture 6
D. Ground Water 6

III. WATER UTILIZATION AND NEEDS

A. Consumptive Uses 10
B. Non-Consumptive Uses 12
C. Summary of Water Use 13
D. Administration and Management of Water in Montana 13
E. Future Water Requirements 14

IV. A PROPOSED WATER RESOURCE PLAN FRAMEWORK

A. Objectives and Scope 15
B. Basic Assumptions 16
C. Study Procedure 17

V. COORDINATION WITH OTHER PLANS

FIGURES

1. Mean annual precipitation in inches.
2. Major drainage basins, stream flow, and larger lakes and reservoirs.
3. Mean annual runoff in inches.
4. Cultivated land use.
5. Unconsolidated rock aquifers.

MONTANA WATER RESOURCES AND PLANNING

INTRODUCTION

The 1967 Legislature of Montana, recognizing that the water resources of the State should be put to optimum beneficial use and not wasted, passed the Montana Water Resources Act of 1967 which created the Montana Water Resources Board to assume the duties of the pre-existing State Water Conservation Board, the Carey Land Act board, and the State Engineer. The necessity and policy upon which this action was taken is clearly stated in Section 89-101.2 of the Act:

It is hereby declared that:

(1) The general welfare of the people of Montana, in view of the state's population growth and expanding economy, requires that water resources of the state be put to optimum beneficial use and not wasted.

(2) The public policy of the state is to promote the conservation, development and beneficial use of the state's water resources to secure maximum economic and social prosperity for its citizens.

(3) The state, in the exercise of its sovereign power, acting through the water resources board, hereinafter created, shall co-ordinate development and use of the water resources of the state so as to effect full utilization, conservation and protection of its water resources.

(4) The development and utilization of water resources, and the efficient, economic distribution thereof, are vital to the people in order to protect existing uses and to assure adequate future supplies for domestic, industrial, agricultural and other beneficial uses.

(5) The water resources of the state must be protected and conserved to assure adequate supplies for public recreational purposes and for the conservation of wildlife and aquatic life.

(6) The public interest requires the construction, operation and maintenance of a system of works for the conservation, development, storage, distribution and utilization of water, which said construction, operation and maintenance is a single object and is in all respects for the welfare and benefit of the people of the state.

(7) It is necessary to co-ordinate local, state, and federal water resource development and utilization plans and projects through a single agency of state government, hereinafter created and to be known as the "Montana Water Resources Board."

(8) The greatest economic benefit to the people of Montana can be secured only by the sound co-ordination of development and utilization of water resources with the development and utilization of all other resources of the state.

(9) To achieve these objectives, and to protect the waters of Montana from diversion to other areas of the nation, it is essential that a comprehensive, co-ordinated multiple-use water resource plan be progressively formulated, to be known as the "State Water Plan."

In order to achieve the objectives quoted above and especially to allow for development of a state water plan (see items 8 and 9 above) the Legislature further spelled out the specific procedure for development and implementation of the state water plan in Section 89-132.1 of the act:

In addition to any other power or duty authorized or imposed by provisions of this code, the board shall be empowered, and a duty is hereby enjoined thereon, to:

(1) Gather from any source reliable information relating to Montana's water resources, and prepare therefrom a continuing comprehensive inventory of the water resources of the state. In preparing said inventory, the Board may conduct studies, adopt studies made by other competent water resource groups including federal, regional, state or private agencies, perform research or employ other competent agencies to perform research on a contract basis, and hold public hearings in affected areas at which all interested parties shall be given an opportunity to appear.

(2) Formulate and adopt, and from time to time amend, extend or add to a comprehensive, co-ordinated multiple-use water resources plan, known as the "state water plan." Said state water plan may be formulated and adopted in sections, said sections corresponding with hydrologic divisions of the state. The state water

plan shall set out a progressive program for the conservation, development and utilization of the state's water resources, propose the most effective means by which these water resources may be applied for the benefit of the people, with due consideration of alternative uses and combinations of uses. Before adoption of the state water plan, or any section thereof, the board shall hold public hearings in the state, or in an area of the state encompassed by a section thereof if adoption of a section is proposed. Notice of said hearing or hearings shall be published for two (2) consecutive weeks in a newspaper of general county circulation in each county encompassed by the proposed plan or section thereof at least thirty (30) days prior to said hearing.

(3) Submit to each general session of the legislature the state water plan or any section thereof or amendments, additions or revisions thereto which the board shall have formulated and adopted.

(4) Prepare a continuing inventory of the ground-water resources of the state. Said ground-water inventory shall be included in the comprehensive water resources inventory described in subsection (1) above, but shall be a separate component thereof.

(5) Publish the comprehensive inventory, the state water plan, the ground-water inventory, or any part of each, and may assess and collect a reasonable charge for said publications.

(6) Promulgate rules and regulations necessary to effect the purposes of this act.

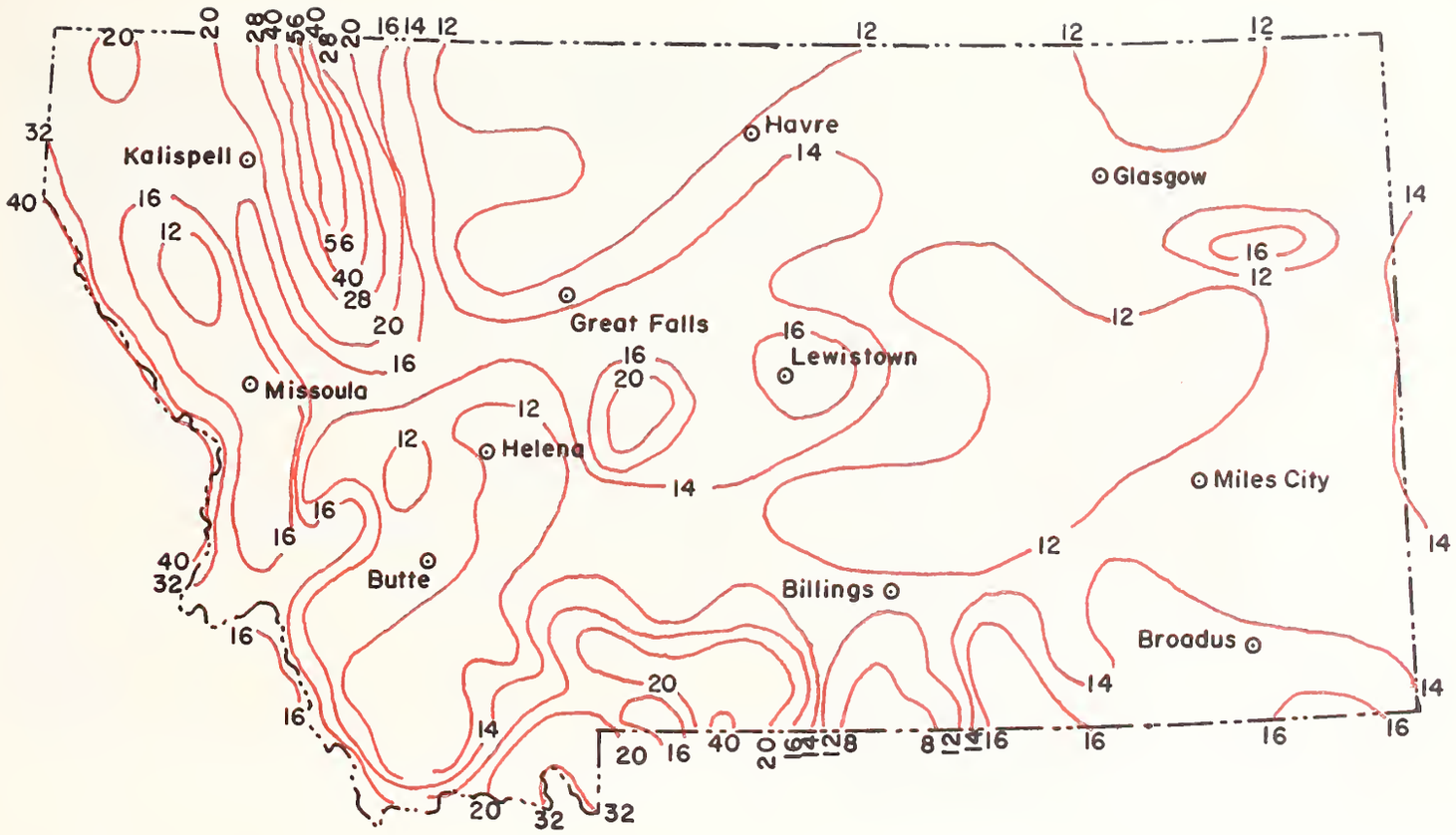
Thus, Section 89-132.1 clearly spells out the scope and objectives of the state water plan and designates the Montana Water Resources Board as the primary state agency responsible for its development.

Although this is the first specific legislation aimed at comprehensive water and related land resource planning for Montana, several activities carried out primarily by State and Federal agencies in the past, were based on some of the same objectives and did, to all intents and purposes, accomplish some planning and development.

One of the first of these efforts was accomplished by the Montana Irrigation Commission which produced county-by-county plans for irrigation developments in the period 1919 to 1921. Creation of the State Water Conservation Board in 1934 resulted in a considerable planning effort primarily on a project-by-project basis. This effort was again irrigation oriented, and further, as a result of Federal agency demands was based primarily on economic relief during the depression of the thirties. Comprehensive planning was not accomplished. However, through the years the Board accumulated a large amount of background data and experience basic to any planning effort. One of the most important factors in supplying background data on water development was the inauguration of the Water Resources Survey under the State Engineer (now Water Resources Board) in 1943. Without this survey it would be virtually impossible to have any reliable information concerning Montana's water use such as number of acres irrigable under existing systems and inventory of water rights for the protection of individuals in the state.

Under the authority of the Flood Control Act of 1944, regional planning by Federal agencies, chiefly the U.S. Bureau of Reclamation and the U.S. Corps of Engineers was initiated. This planning involves Montana, especially in the Missouri River Basin, under the overall guidance of the Missouri Basin Inter-Agency Committee. Similarly, the Columbia Basin is being investigated by the Columbia-North Pacific Region Comprehensive Framework Study under the supervision of the Pacific Northwest River Basins Commission, a combined Federal-State regional planning group. Other plans involving regional problems were made to support the Columbia River Water Treaty, adopted about ten years ago, and the Columbia Interstate Compact Commission which has never been adopted by all of the northwestern states. In addition to planning by the foregoing agencies numerous river basin studies by the U.S. Bureau of Reclamation, the U.S. Corps of Engineers, and the Bonneville Power Administration have been made in both the Missouri and Columbia basins and contain considerable planning for various projects. A very small area in extreme northeastern Montana falls in the Souris-Red-Rainy drainage, and the Souris-Red-Rainy River Basins Commission is presently conducting a planning study. Also a small area in Glacier Park and adjacent Glacier County falls within the Hudson Bay Drainage.

This summary, brief as it is, shows that comprehensive state water resource planning aimed at the unique water resource problems of Montana has not been undertaken in the past but that much information and experience has been developed which can be used in such an endeavor. In the following two sections of this brochure it is clearly demonstrated that such planning is needed and the last sections outline a proposed framework for a comprehensive water resources plan.



MONTANA
MEAN ANNUAL PRECIPITATION
(IN INCHES)

FIGURE 1

MONTANA WATER RESOURCES

Precipitation

The original source of all water used for practical purposes in Montana is from **precipitation.** As shown (Figure 1), long-time averages of annual precipitation range widely, from over 56 inches in the northwest to less than 6 inches in the south-central part of the State. By far the greater part (more than ¾) of the state receives 14 inches or less of precipitation annually although the state's mean annual is commonly said to be about 15 inches. Heavy precipitation occurs only in the high mountainous areas where about 60 percent falls during the snow storage period between October and April. East of the Continental Divide 65 to 80 percent of the precipitation occurs between April and September. During the same period an average of about 50 percent of the precipitation falls in the mountainous valleys west of the Divide. Although winter temperatures are conducive to snow storage in the mountains, obviously this wide range of occurrence leads to the necessity of utilizing artificial storage structures to make the most efficient use of the water. Further, since chinook winds of mid-winter and spring deplete much of the snow storage on the foothills and plains east of the Continental Divide more structures are required. These structures store water and modulate the flow of streams so that greater amounts are available in times of need and less flood water is passed downstream without being used. In normal years plenty of water is available for present demands. However, in time of drouth (especially during low flow and low precipitation periods) water shortage is a common problem more critical in eastern Montana but often critical throughout the State. During such periods artificial storage

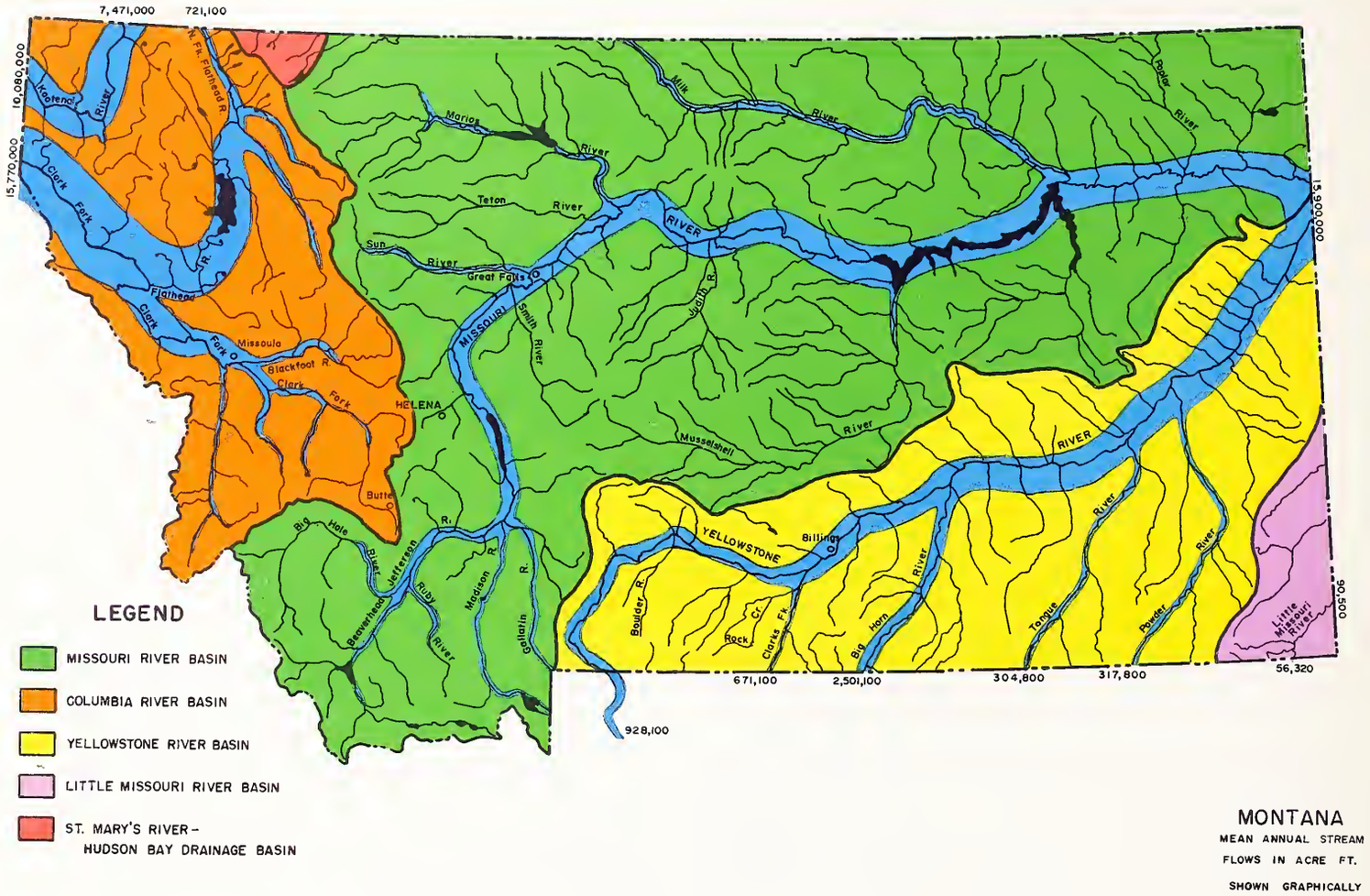


FIGURE 2
Major drainage basins, stream flow, and larger lakes and reservoirs.

reservoirs become especially valuable and popular demand for them grows. Even in normal or above-normal periods and certainly in drouth years in nearly all parts of the State precipitation alone (without additional storage and flow modulation) will not support further significant agricultural, industrial, or municipal development if considerably larger quantities of water are required.

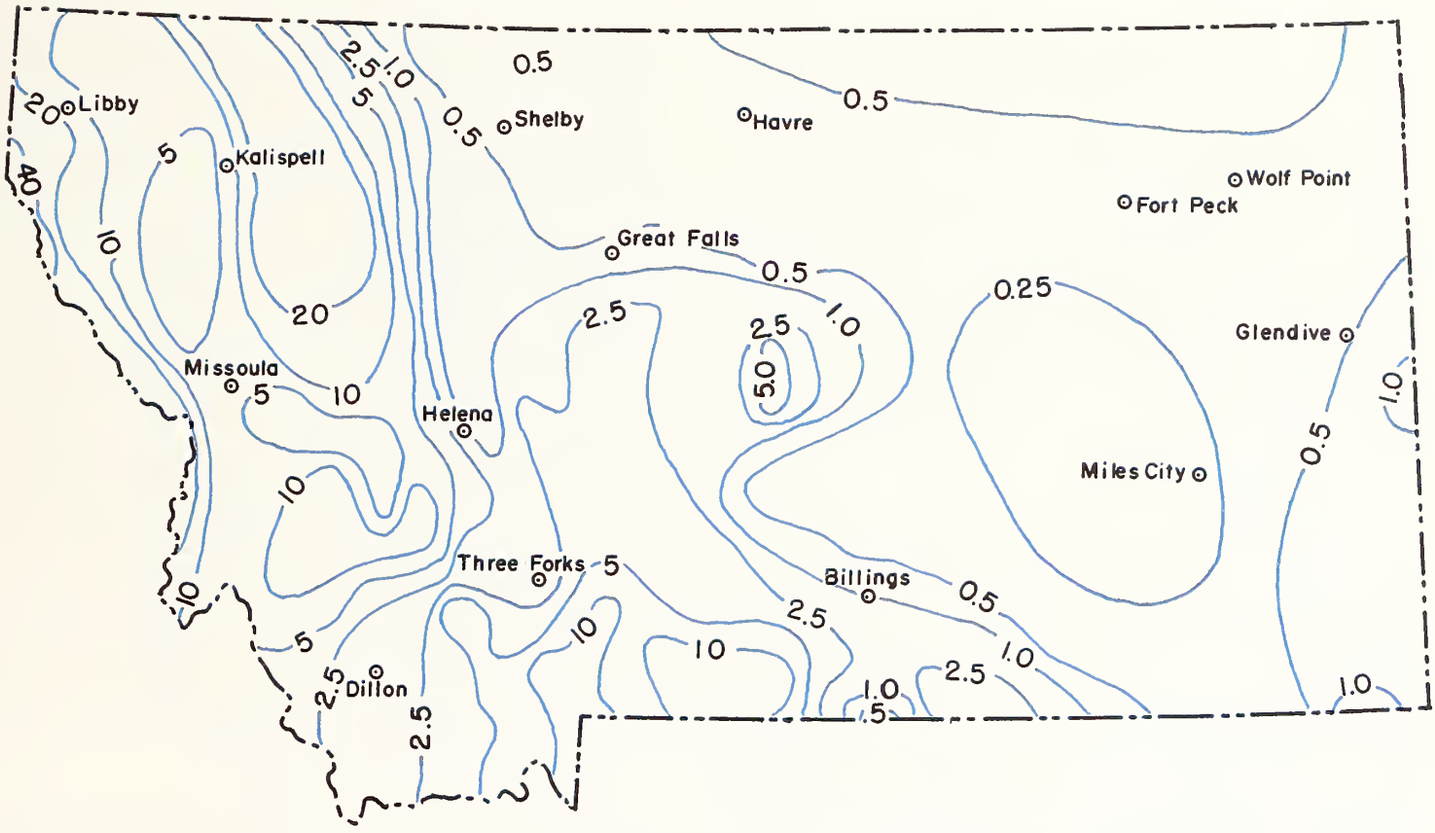
SURFACE WATER

The water in streams, lakes, and reservoirs is commonly called **surface water** and constitutes the main source of supplies commonly used by man in the State. It is also the water that makes Montana so scenically and recreationally attractive, and it supports a numerous and varied population of fish and wildlife.

This water comes from precipitation and collects in and is transported by a stream system which is reasonably well distributed in the west but not so well in the eastern part of the State. Figure 2 shows major drainage basins and larger lakes and reservoirs. Figure 3 shows **mean annual runoff.**

Mean annual runoff varies from about 40 to less than 0.25 inches and averages about 3.5 inches. More than one-half of the State has less than 1.0 inch of runoff, primarily in the east. The high mountainous areas have relatively high runoff. The runoff is strongly influenced by climatic factors, especially precipitation and temperature, and to a lesser degree by other physiographic and geologic factors such as topography, geology, and vegetation. The combined influence of all these factors results in two fractions of runoff:

(1) **base** or **dry-weather flow** which is supplied primarily by discharge from the ground-water reservoir and



MONTANA

MEAN ANNUAL RUNOFF

(IN INCHES)

FIGURE 3

(2) **flood flow** which comes from the spring melt and from large storms at other times of the year. Montana streams typically reach a peak rate of runoff in May or June from spring rains and from the snow melt which begins in late March or April. Usually by September the discharge has receded to base flow although there is commonly a small increase resulting from decreased use by vegetation and by the inception of fall rains. This base flow rate continues until March when the minimum flow occurs, to be succeeded by the beginning of the snow melt. In general, more than one-half of the runoff from Montana streams occurs during the three months (May, June, July) of the spring flood. This runoff pattern is of prime importance to the development of Montana's water resources.

Estimates of the amount of water originating in Montana, leaving the State, and entering and leaving by streams, based on average annual flow values (millions of acre feet) calculated in 1959, are given in Table 1.

TABLE 1

Millions of Acre Feet

	Enters State	Leaves State	Originating in State (does not include evapotranspiration)
Missouri Basin	6.73	16.70	9.97
Columbia Basin	8.16	25.31	17.15
Hudson Bay Basin	0.00	.86	.86
	14.89	42.87	27.98

These values might be compared with estimates of water use in Montana. Presently, estimates are that between eight and ten million acre-feet of water are diverted for irrigation, stock, domestic, public supply, and industrial use of which about five million acre feet are consumed, i.e., evapotranspired in the process of use.

Based on relatively sparse data collected by the U.S. Geological Survey the quality of the streams of western Montana, roughly west of a line through

Havre and Billings, is good with low concentrations (less than 500 parts per million) of dissolved solids. The water is of the calcium bicarbonate type. East of this line and north of the Missouri River the water is of the sodium bicarbonate type with relatively high (500 to 5,000 ppm) concentrations of dissolved solids. The remainder of the State is characterized by water of sodium sulfate type with relatively high (200 to 5,000 ppm) concentrations of dissolved solids. The differing quality of water reflects the geology over which the streams flow as well as the amount of use of the water as it flows toward the eastern border of the State.

On the basis of more or less comparable data compiled by the U.S. Geological Survey the sediment yield of streams in western Montana shows east to west degradation from the foot of the Rockies west with relatively low sediment yield (less than 99 tons/sq. mi. of drainage area). In the eastern part (from Yellowstone, Garfield, and Valley Counties eastward) streams contain considerable sediment (300 to 500 tons/sq. mi.). An intermediate area in central Montana from the foot of the Rockies to a line through Havre and Billings has somewhat lower sediment yields (100 to 299 tons/sq. mi.) than those to the east and the highest yields (over 500 tons/sq. mi.) occur in north-central Montana in Phillips, Blaine, Valley, and parts of Fergus, Petroleum and Garfield Counties more or less within the outcrop area of certain silty shales and clay formations. As with water quality, sediment yield in streams rather clearly reflects the character of the rocks over which they flow although in some areas transport of sediment has been accelerated by the actions of man and animals.

Temperature of the flowing streams depends upon the season and the snow-melt period—near the freezing point in the winter and reaching as high as 70 to 80 F. in August. In the lakes and reservoirs surface temperatures may vary with the season but waters released from large storage reservoirs approximate mean annual air temperature.

In contrast with stream waters of many states, Montana's waters are relatively free from pollution. Only in local areas in a few places have serious pollution problems been reported.

SOIL MOISTURE

Much water from precipitation that does not run off as surface water or is not evapotranspired infiltrates the land surface and moves into the soil to varying depths. The part of this water which is temporarily captured by molecular, capillary, and other forces and is subject to use by plants is commonly called **soil moisture.** Thus the **soil moisture reservoir** occupies that area between the land surface and the bottom of the root zone, that is, the depth to which plant roots reach. On a world-wide basis this soil-moisture reservoir stores and yields large quantities of water. It may be considered basically as one of the most important natural sources of water since it nourishes most of the plant foods for men and animals. In Montana the soil-moisture reservoir underlying our vast acreages of "dryland" farms is basically responsible for production from those farms as well as for the condition of the range and forests. In normal and above-normal precipitation periods "dryland" farming is highly profitable but, since the amount of soil moisture is almost directly dependent upon the vagaries of precipitation, it becomes a precarious if not unprofitable endeavor during extended drouth periods. In spite of this, dryland farming has proved to be a highly productive practice in Montana (Figure 4).

Man's chief endeavor to modulate the broad variations in soil moisture, as well as to divert additional supplies of water to otherwise permanently moisture deficient soils, has been the practice of irrigation. The main purpose of irrigation is to artificially maintain a favorable soil moisture condition by applying appropriate amounts of water during critical periods in the growth cycle of selected plants. Since there is a broad variety of beneficial plants, soils, and an almost infinite variation in moisture conditions between arid and humid limits the amount of water applied in irrigation practice may range from none ("dryland" farming practice) through various degrees of supplemental application including such practices as water-flooding or water-spreading often only once a season, to growing of crops with complete dependence on irrigation throughout the growing season. In Montana, with its wide variation in climate, soils, and topography all variations of irrigation practice are followed in one place or another and long-range agricultural productivity varies almost directly with the capability of farmers and ranchers to follow the appropriate practice at a given time. Present estimates indicate that at least 3¼ million acres in Montana are or have been irrigated (Figure 4). Various methods of land treatment are also applied to retain, increase, or decrease the soil moisture.

GROUND WATER

A part of the water from precipitation and from streams, canals, irrigation, and the like percolates

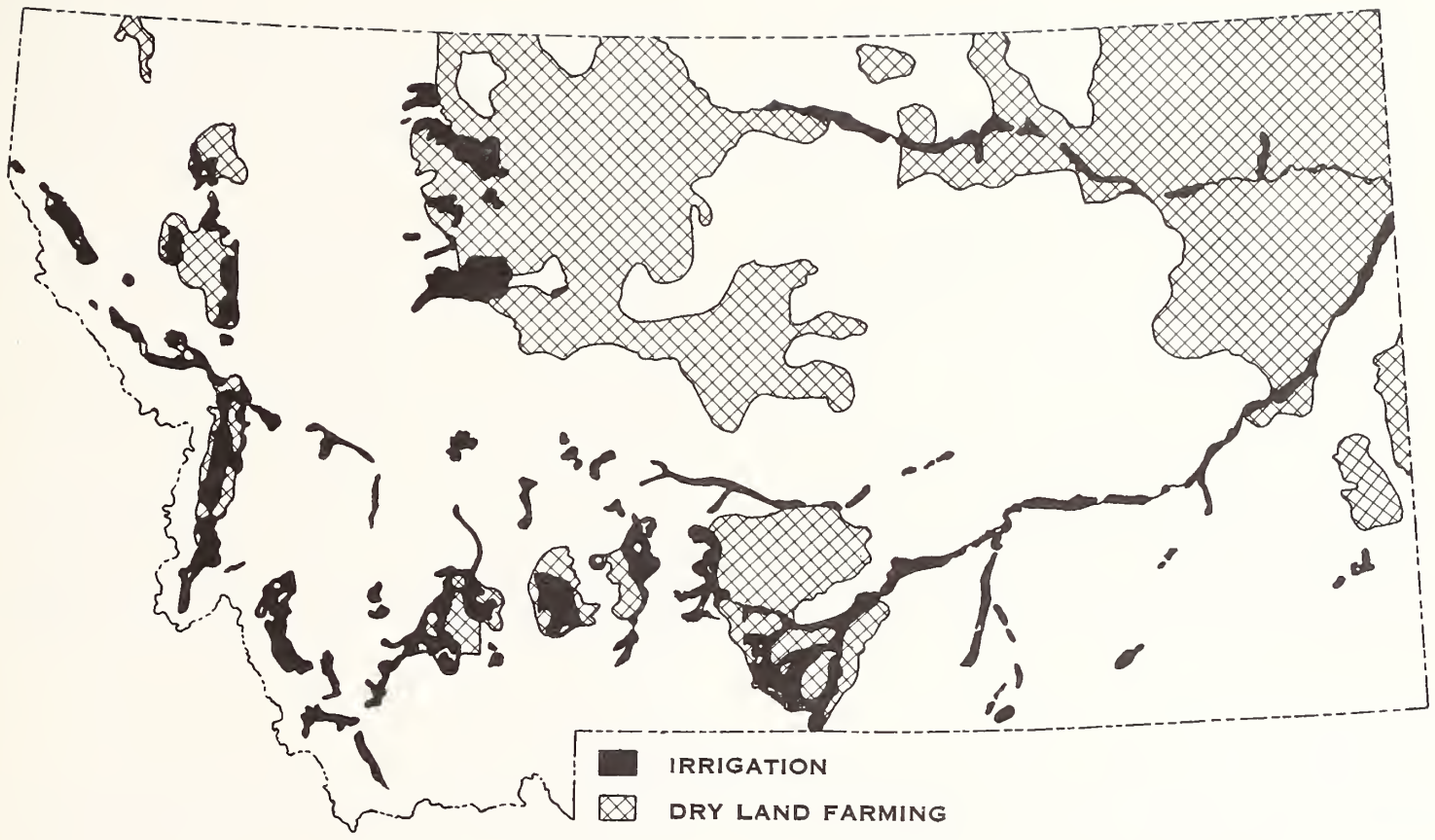


FIGURE 4
CULTIVATED LAND USE, MONTANA
Source: The 1959-1960 Montana Almanac

deeply into the soil, through the soil-moisture reservoir, and contributes recharge to a saturated zone known as the **ground-water reservoir.** Commonly within this zone all, or nearly all of the openings between soil or rock particles and fractures, solution channels, caves and other openings are filled with water. The upper boundary of the saturated zone is called the **water table** which may intersect the land surface or a surface-water body or may occur at varying depths within or beneath the soil-moisture reservoir. The lower boundary of the saturated zone is commonly thought to occur normally at great depths where pore space and fractures practically disappear. However, for practical purposes the lower boundaries of most ground-water reservoirs are usually arbitrarily selected rock units of relatively very low permeability if, indeed, such boundaries are delineated at all. For many reasons, but primarily because of technological, economic, or poor water quality conditions, deep ground water is seldom exploited, and then almost solely for industrial purposes. Wells of more than a couple of thousand feet in depth are seldom drilled. More detailed knowledge of ground water is, therefore, primarily available in shallow zones of fresh water. Much of the knowledge of deeper occurrences comes from drilling, testing, and operating oil and gas wells.

In determining the availability and occurrence of exploitable supplies of ground water, we are concerned chiefly with two characteristics of the geologic medium in which the water occurs—its **permeability (transmissivity)** or capacity to allow water to pass through it and its **porosity (storage capacity)** which is the ratio of the volume of open space or interstices to the total volume of the rock, usually expressed as a percentage of the total volume. Rock units with relatively large permeability are known as **aquifers** and those with relatively small permeability are called **aquicludes.** Other characteristics of a specific rock unit that we must determine are its thickness, lateral extent, and continuity; its position relative to other rock units; and its depth or accessibility. The chief physical characteristic of water that we must know is its **potential** or **head** which is

related to the depth from which it must be pumped. All of these characteristics relate primarily to the quantity of water available to wells and the feasibility of exploiting it for water supply. Knowledge must also be gained about the **chemical quality** of the water—such as the amount, type, and distribution of minerals and other substances that are dissolved in it.

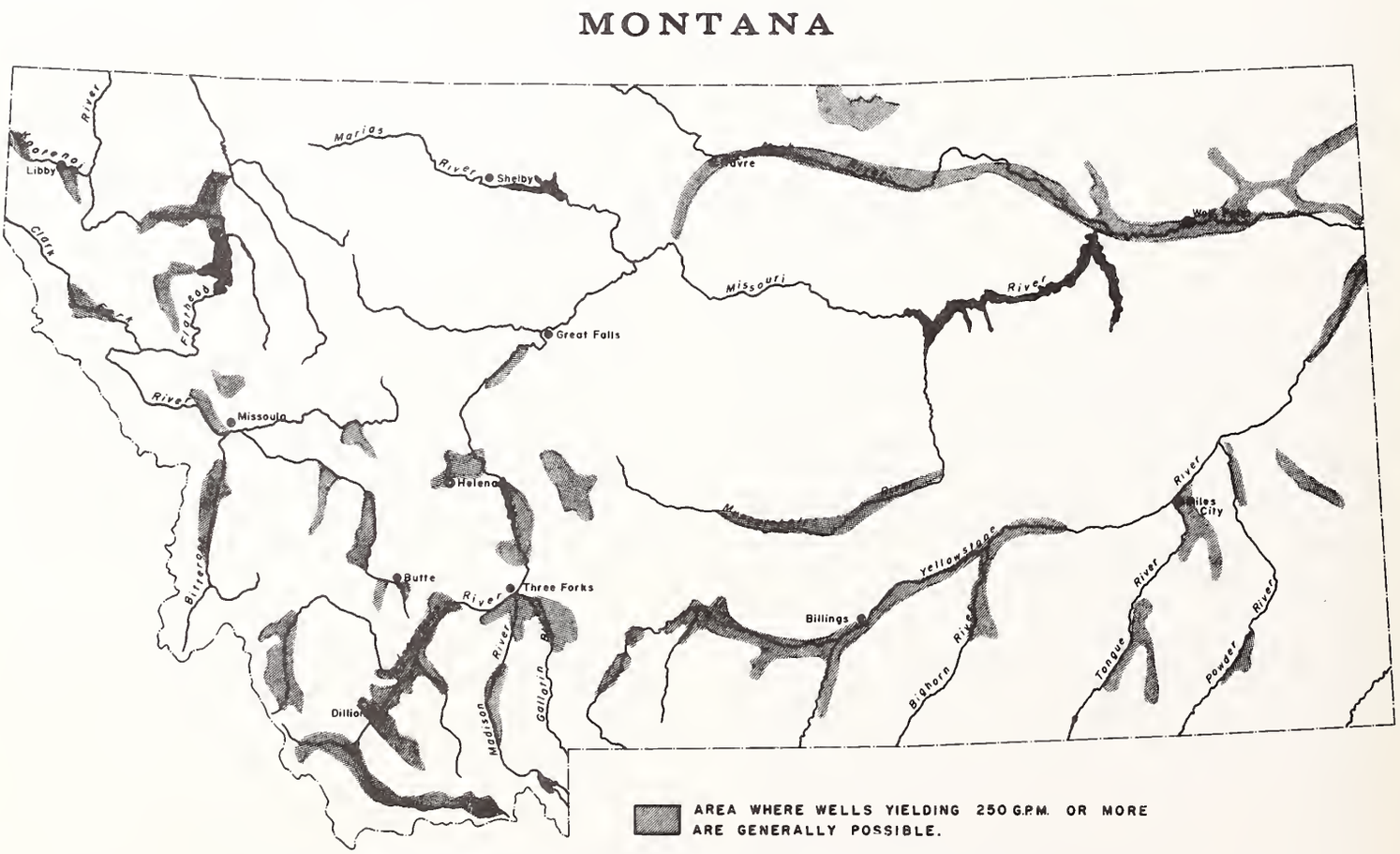
For practical reasons ground-water reservoirs may be classified into two large categories:

(1) Those made up primarily of unconsolidated rocks and aggregates usually of fluvial, eolian, or glacial origin and possessing chiefly **primary** permeability—that is the openings in which water is stored in between the discrete particles making up the rock and

(2) Those in consolidated and indurated rocks which possess chiefly **secondary permeability** where the openings are fractures, solution channels, caves, lava tubes and the like. Some consolidated rocks such as certain sandstones and conglomerates may possess primary as well as secondary permeability whereas carbonate, crystalline, and volcanic rocks may possess only secondary permeability.

In Montana both types of ground-water reservoirs are recognized and occur commonly although neither type is uniformly distributed throughout the State. Figure 5 shows recognized areas of **unconsolidated rock reservoirs** that are either exploited or exploitable for ground-water. Although these occur in many parts of the state, none occur in many areas. As might be expected most of these reservoirs are closely associated with presently occupied or abandoned stream channels and are hydraulically connected to streams, lakes, or reservoirs. In most of them water occurs at shallow depths in moderate to highly permeable materials, chiefly sand and gravel, and is of a quality satisfactory for most uses.

In general the chemical quality of ground water is similar to the associated streams as described in the section on surface water. Thus calcium bicarbonate waters with low dissolved solids may be found in western Montana, sodium bicarbonate waters with low to high dissolved solids in northeastern Montana, east of Havre



Map showing areal distribution of water-bearing unconsolidated rocks and potential well yields. Modified from data published in Montana Bureau of Mines and Geology (Special Publication #28)

FIGURE 5

and north of the Missouri River, and sodium sulfate waters with moderate to high dissolved solids in southeastern Montana, east of Billings and south of the Missouri River. Most of the unconsolidated rock reservoirs are readily recharged from associated streams and diverted irrigation water and by precipitation. Notable exceptions to this are the high bench gravel reservoirs in north-central and northeastern Montana north of the Missouri River which are recharged by precipitation alone. All of these reservoirs discharge into streams or into the atmosphere by the process of evapotranspiration.

The nature and extent of **consolidated rock reservoirs** or aquifers are not so well known because they have not been so highly exploited and, in some ways, are much more difficult to delineate and evaluate than the unconsolidated rock reservoirs. They are most important as aquifers east of the Rocky Mountains where they are widely used to provide water supplies for small towns and for some industrial, domestic, and stock use. In general, these aquifers are exploited by small yield wells but very large flows have been encountered in some areas. The most likely consolidated aquifers for large fresh yields are some sandstones and carbonate rocks that do not occur at great depths. The chemical quality of water from the consolidated rocks is highly variable. Generally where they are shallow the water is usable for most purposes and where they are deeply buried the water is more mineralized and less satisfactory (or not satisfactory at all) for most common uses.

The consolidated rock aquifers are recharged from precipitation, streams, and from the unconsolidated rock reservoirs. The source and amount of recharge to them is difficult to determine. In general, it is much more limited than recharge to the unconsolidated rock reservoirs. The principal avenue of discharge from the consolidated rocks is springs and seeps many of which occur at relatively long distances from the major recharge areas.

Springs and seeps are the most evident discharge points for ground water and the number and variety of them, both as to volume of discharge and nature of occurrence, are very large. They form an important source of water supply for all common uses and are especially important as sources for domestic and stock-watering uses. Estimates of total discharge and use from springs in Montana are unavailable but ultimately spring water that is not evapotranspired or otherwise consumed flows into streams and is accounted for in discharge measurements of the latter. The quality of springs varies widely and in most instances is essentially the same as the ground and surface water in the vicinity of the spring. However, numerous thermal and mineral springs are known that usually contain relatively high concentrations of mineral constituents and have relatively high-temperature water.

According to inventories by the U.S. Geological Survey, industry, agriculture, and public water supply are the heaviest users of ground water in Montana. The many hundreds of rural domestic and stock wells are the primary source of supply for these uses and are highly important to the well being of thousands of rural Montanans, especially east of the Rocky Mountains. Only a fraction of one percent of total irrigation diversion comes from wells, mostly from the unconsolidated aquifers. About one hundred municipalities are supplied exclusively from wells and perhaps twenty use ground water in conjunction with surface water.

Estimated withdrawal of ground water from wells in 1965 is given in the following table in millions of gallons a day and thousands of acre feet a year (modified from estimates by the U.S. Geoligical Survey):

	1965	
	M G D	1,000 ac. ft./year
Public Supplies	29	33
Domestic	10	11
Stock	18	20
Crops	40	45
Industrial		
Fresh Water	25	28
Saline Water	3	3
Total	125	140

Reliable estimates of the amount of ground water available for use in Montana have not been made. However, it is known that very large supplies, certainly more than tenfold present use can be developed. Such development should be preceded by studies to determine the effects on the aquifers and on surface-water supplies.

Most of the unconsolidated rock aquifers are situated so that some form of conjunctive use of ground and surface water can be practiced. For example, heavy pumping of such aquifers might serve to save crops and cropland, and help maintain minimum flows needed for power generation, quality control, and conservation of wildlife in drouth years, whereas in wet years pumping could be stopped and flood waters be used to recharge the ground-water reservoirs.

WATER UTILIZATION AND NEEDS

The many uses of water may be listed in two large categories for practical purposes:

(1) **Consumptive Uses** and

(2) **Non-Consumptive Uses**

Only broad estimates of these uses are available and much work needs to be done to obtain more accurate water use data in Montana. Available estimates, however, give a reasonable base to broadly compare available water with water presently used and with water needed for the future. They also allow a tentative basis for objectively examining some of the problematical aspects of use and management of water resources that presently are attracting much public attention.

CONSUMPTIVE USES

These include all uses of water that result in ultimate disposition to the atmosphere or that otherwise render some or all diverted water unavailable for further beneficial application. In Montana the chief consumptive uses include crop production, industrial (including mining and steam-power generation), public supply, domestic, and stock watering. Obviously these applications do not equally consume water and seldom, if ever, is all diverted water consumed.

Irrigated alfalfa near Fairview, Montana.

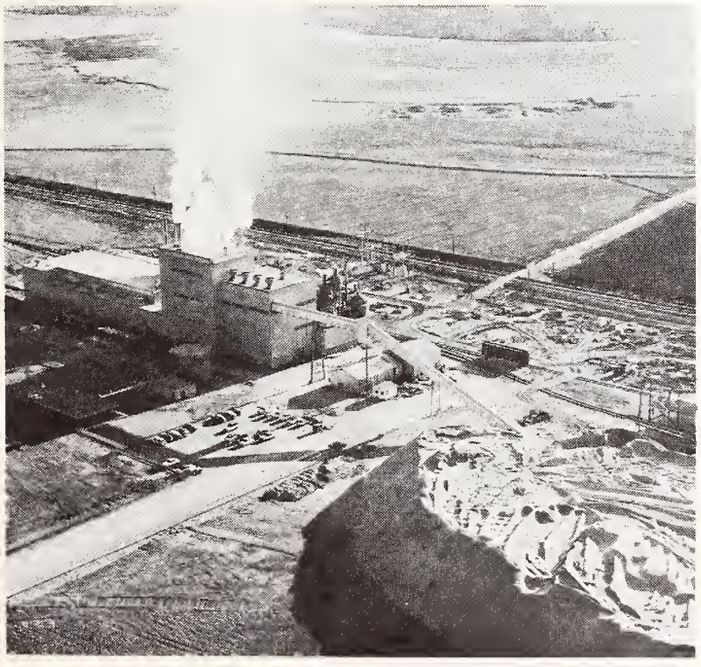
Crop Production. Irrigation not only diverts the greatest volume of water in Montana but consumes the greatest proportion of diverted water. Returns of usable water under conventional practices are estimated to range from 40 to 70 percent of total diversions. Thus, of the estimated 10 million acre feet of water diverted annually for crop production, 3.75 million are estimated to be consumed. This includes not only full-season irrigation but part-time or supplemental as well as water flooding of cropland and water spreading. Only a small quantity of ground water, less than one percent of total irrigation diversion, comes from wells which are chiefly in the unconsolidated rock reservoirs. Nearly all irrigation water is used to raise crops, chiefly feed to support the livestock industry.

The Columbus Diversion Canal — a Water Resources Board Project in Stillwater County.

Industrial. The second largest diverter of water in Montana is industry (including steam-generation power plants and mining). Most of the water is used for cooling although some processing is also done. Return flow of water from cooling and related activities is usually above 90 percent of diversions even though some water is consumed in processing. Mining, exclusive of oil and gas, uses considerable water; about 18.3 billion of gallons in 1962. Large quantities of water are diverted for secondary recovery of oil and gas, about 4 million gallons a day in 1965; of this amount about one million gallons a day were fresh and the rest was brackish or saline.

The recently completed J. E. Corette steam-electric generating plant in Billings.

About one-sixth of the industrial water comes from ground water and five-sixths comes from surface water. Most, if not all of the saline or brackish water comes from wells. About 170 million gallons of water a day were diverted in 1965 for industry of which about 18 million were consumed.



The Waldorf-Hoerner Paper Products Company plant near Missoula.

Public Supplies. Public water supply diverted about 100 million gallons a day in 1965 of which about 18 million gallons a day were consumed. About 115 municipalities were supplied exclusively from wells and about 20 use ground water in conjunction with surface water while about 40 use Xsurface water exclusively. A total of about 450,000 people are served by municipal water supplies and the average daily use per capita is given as 212 gallons most of which is returned. In Montana about one percent of the water diverted goes to air conditioning, about 16 percent to industrial and commercial, and the remainder is used domestically (drinking, sanitary purposes, lawn-watering, etc.).

Rural Domestic Use. About 10 million gallons a day were used in 1965 in Montana for this purpose with more than 90 percent coming from ground water and less than 10 percent coming from surface water. Only about 10 percent of this water is consumed.

Stock wells like this one near Helena are commonly used in the semi-arid valleys and plains.

Stockwatering. About 34 million gallons of water a day are diverted to water stock of which an estimated 30 percent is consumed. This high consumption rate is not a result of animals drinking the water but because of high evapotranspiration losses from watering places.

Summary. In the following table estimates of diversions and consumed water based on U.S. Geo-

logical Survey and other studies are given in acre feet a year.

Surface Water

Use	Diverted	Consumed
Crop Production	10,000,000	3,750,000
Public Supplies	79,000	8,000
Industrial	169,000	17,000
Rural Domestic	1,000	100
Stock	18,000	6,000
	10,267,000	3,781,100

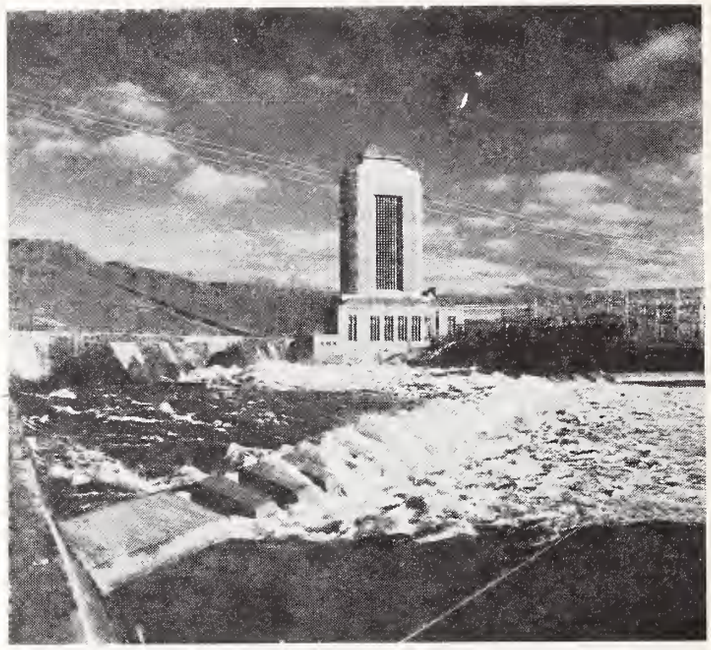
Ground Water

Use	Diverted	Consumed
Crop Production	45,000	20,000
Public Supplies	33,000	3,000
Industrial	31,000	3,000
Rural Domestic	11,000	1,000
Stock	20,000	7,000
	140,000	34,000

NON-CONSUMPTIVE USES

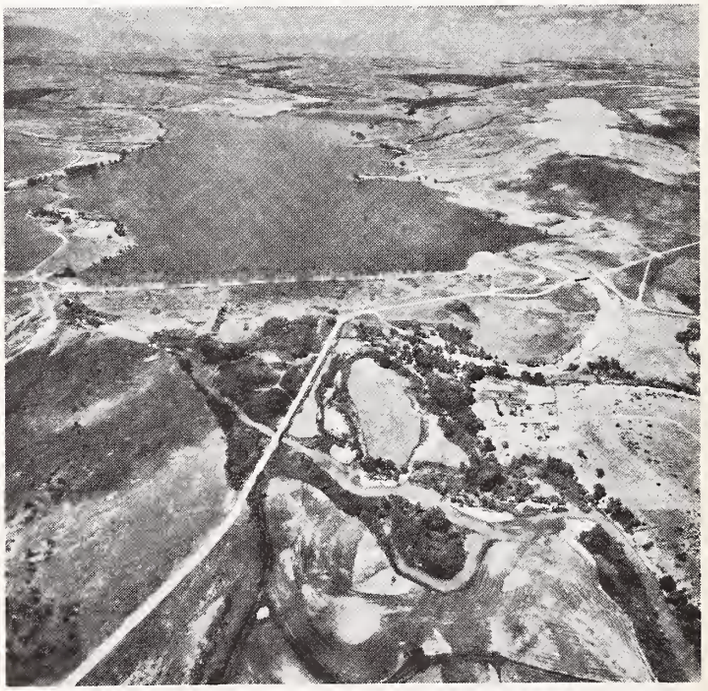
Non-consumptive activities utilize water to accomplish work or fulfill some other more or less beneficial function. Chief among these are hydropower generation, navigation, dilution (quality control), recreation, and development and maintenance of favorable habitats for fish and wildlife. These uses normally place constraints in some degree or another upon other applications, usually in terms of timing and type of use, but actually they directly consume no water. However, considerable quantities of water may be evaporated as a result of development of reservoirs and other works needed to store, transport, or otherwise modify the natural environment to accommodate the particular use.

Recreation and fish and wildlife requirements may include, for example, uncommonly high quality standards which place a constraint on other uses that is essentially equivalent to consuming water. Thus, indirectly non-consumptive uses may result in considerable consumption of water. Practices such as dilution and transport of waste may degrade water to the point where it is essentially unusable and therefore, to all intents and purposes, is consumed. In 1962 it was estimated that of about 2 million acre feet of water annually evaporated from reservoirs, lakes, and streams in Montana, more than 1.25 million acre feet were lost from the principal regulated lakes and reservoirs with a usable storage of 5,000 acre feet or more. Much of this storage is used to produce dependable firm power



Fort Peck Dam and power house on the Missouri River.

and to maintain reasonable levels for recreation although it is also used for other purposes. In Montana, hydropower generation involves more control of water than any other non-consumptive use and navigation is the least important. Presently water for quality control (dilution) and for conservation (recreation and fish and wildlife) place only relative small constraints on other uses. However, increasing demand will inevitably require increasingly alert management and control to avoid conflict between all users.



Cooney Dam and Reservoir — a Water Resources Board project for irrigation and much incidental recreation.

SUMMARY OF WATER USE

Present water diversion in Montana is estimated to total about 10 million acre feet a year of which about 3.8 million are consumed annually by all consumptive uses. In addition to this approximately 1.25 million acre feet are annually evaporated from the principal regulated lakes and reservoirs with a usable storage of 5,000 acre-feet or more and about 0.75 million acre feet are evaporated from large unregulated lakes, principal streams, small lakes and reservoirs, and small streams.

Water-based recreation is a major pastime in Montana.

ADMINISTRATION AND MANAGEMENT OF WATER IN MONTANA

Montana Water Law is the basic factor involved in administration and management of the water resource. As in other western states the law is based upon the **doctrine of appropriation** which adheres to three basic concepts:

(1) That the waters of the State constitutionally belong to the State and that an individual or other entity can only obtain a right of use which is legally regarded as a property right;

(2) that the first user in time holds first priority in right; and

(3) that only that water put to beneficial use is the amount to which the appropriator has a right, regardless of the amount claimed by the appropriator.

Appropriation of surface water on unadjudicated streams is accomplished by the claim to a right being publicly announced and filed with the Clerk and Recorder in the County of appropriation. This procedure has many times been recognized by the Courts and is generally accepted by the public. If a stream has been adjudicated, the appropriator must petition the District Court and all decreed right holders must become parties to the action. Water rights may be lost in two ways, either by abandonment or by adverse use. They are questions of fact and are determined as such. According to the Montana Water Code (Title 89, Sect. 2113), rights to use ground water may be obtained in two ways:

(1) Application of ground water to beneficial use before January 1, 1962 is recognized as a water right, and

(2) by filing a notice of ground-water appropriation with the County Clerk in the County of Appropriation. In controlled ground-water areas a permit from the Montana Water Resources Board has also been required in order to appropriate ground water since January 1, 1962.

Although a definite and accurate appraisal is not available, probably most, if not all of the water available from streams, at least in low flow periods (during extended drouths) is appropriated but only a few streams have been adjudicated. Thus, in most areas of the State probably only flood waters, not now permanently used, are available for new use. In a State where more than one-half of the total runoff occurs during the spring flood and some flooding occurs at other times, a large quantity of water can be made available for beneficial use by the construction of storage reservoirs and other flow modulation works.

State and other officials and technologists have long recognized this situation and have undertaken many measures to store and beneficially use flood waters. Although numerous small diversion and power dams were built previous to the early 1930's, it was at this time that large-scale development of storage space for flood or so-called "surplus" waters really was initiated. This took place on both Federal and State levels with the initiation of construction of Fort Peck Dam and with establishment of the Montana State Water Conservation Board (since 1967, the Montana Water Resources Board).

Montana law also provides for five types of districts that may be established for the purpose of studying, planning, developing and conserving water and related land resources, and providing flood control. These include:

(1) County water and sewer districts,

(2) drainage districts,

(3) irrigation districts,

(4) state soil and water conservation districts, and

(5) water conservation and flood control districts.

The Waterways Treaty of 1909 between Canada and the United States involving the waters of the St. Mary and Milk Rivers, and the Yellowstone Compact of 1950 between Wyoming, North Dakota, and Montana involving the Yellowstone River place constraints upon the use and therefore the administration and management of water in Montana.

In 1955 a State Water Pollution Control Council was created and shortly thereafter adopted standards for water quality. In 1967, in accordance with the requirements of the Federal Water Pollution Control Act of 1965, these standards were updated and accepted by the Federal government. Both these quality standards and the public water supply standards of the Montana State Board of Health are constraints that must be recognized and conformed to in administrative and managerial activities.

In addition to governmental and quasi-governmental organizations, two "private" or "corporate" types of organizations have commonly been formed to develop and manage water in Montana. One of these—Waters Users' Associations—was developed to purchase, manage, and distribute the "surplus" water stored in dams constructed by the Montana State Water Conservation Board (since 1967, the Montana Water Resources Board). The other—private ditch or canal companies — was established primarily to facilitate distribution of irrigation water in relatively local areas. Most irrigation development in Montana has been accomplished by private individuals and private organizations. Presently about 174 private ditch or canal companies, maintaining projects of greater than 500 acres, serve about 600,000 irrigable acres and 29 Water Users' Associations distribute water to about 244,000 irrigable acres from Montana Water Resources Board Projects.

Forty-five active irrigation districts reportedly have been established under the irrigation district law and twenty-two of these are supplied by State (Water Resources Board) or private projects and furnish water for 123,500 irrigable acres; seventeen are U.S. Bureau of Reclamation projects supplying 282,800 irrigable acres; and six are U.S. Bureau of Indian Affairs projects supplying 194,400 irrigable acres.

FUTURE WATER REQUIREMENTS

Presently, precise estimates of future water requirements within an accurate time framework for Montana is not possible for a number of reasons:

(1) Although considerable data is available on precipitation, stream discharge, water quality, and temperature; present amount of water used and patterns of that use; present and potential storage sites; and general occurrence and availability of fresh ground water, we lack much necessary information on the amount of ground water available for use and its location, on the relation of surface and ground-water bodies relative to use, and on the availability of land best-suited for various irrigation practices (especially in the Missouri Basin).

(2) Far more accurate basic economic and other information is needed in order to evaluate, not only present worth of our water supplies, but future values.

(3) The water resource is only one factor in the development of a region although, in Montana, perhaps one of the prime controlling factors. Thus, it must be assumed that somehow and for various reasons people will migrate to and settle in the State and pursue activities that require water.

(4) There is no dependable indicator of the timing of population increase, that is, whether it will result in a steady growth primarily as a result of intrastate population increase or occur as one or a series of rapid influxes involving migration from out of state in a short time.

(5) There is little to indicate what these people will do or will wish to do in terms of agricultural, industrial, or recreational use of water or where they will wish to do it.

Thus, prediction of future water requirements is not a simple matter of feeding data into a computer and recording the answers generated by the machine.

Another way of estimating requirements is to evaluate:

(1) How much water is ultimately available starting with the streamflow and ground water that originates in the State and the amount that can be made further available by modulation of flow and other management practices utilizing available surface and ground-water storage under the constraints

of needs for conservation water (water-based recreation, scenic purposes, and fish and wildlife preservation), and needs for water quality control. Such an evaluation can be made with reasonable accuracy on the basis of present knowledge and could afford a reasonable maximum estimate of available water on the average, and during periods of maximum and minimum flow.

(2) Determine maximum potential requirements for crop production, industry, domestic, municipal, conservation, and quality control needs based on our best estimate of technological development, land and mineral resources, recreation and fish and wildlife protection and development and quality protection. These determinations should be considered as tentative and subject to change as development proceeds and as new information, technical methods, and developmental trends become evident.

(3) Balance the above maximum requirements against the maximum availability of water taking into account allowances for the constraints imposed by drouth (primarily determined from the historic record) and flood control. This "balancing" procedure should actually amount to development of optimal water use over a long period without consideration of short term development.

This process should yield a first rough estimate of whether Montana has a water shortage or surplus relative to the water that originates within the State. Further, it should yield evidence as to alternative procedures that might be followed regarding possible interbasin transfers within the State, possible alternatives of allocation of water to the various uses, legal control of water, managerial control, and it should indicate the general position that Montana should assume regarding long-range regional transfers of water out of, into, and through the State. Further, it will furnish a rational realistic framework within which to work out answers to short-term developmental problems posed by the erratic, more or less indeterminable factors of population growth and human desires, among other parameters.

This procedure does not eliminate the possibility of developing needed projects that are obviously desirable or necessary in the near future and it should not be used as a device to even postpone such developments. On the contrary, it provides a necessary long-range framework and background into which such developments can be fitted and, perhaps, be more efficiently and appropriately planned and executed.

A PROPOSED WATER AND RELATED LAND RESOURCES PLAN FOR MONTANA

The Montana Water Resources Act of 1967 (Title 89-101.2, Montana Code) states that "the public policy of the State is to promote the conservation, development, and beneficial use of the State's water resources to secure maximum economic and social prosperity for its citizens" and clearly designates the Montana Water Resources Board as the action State agency which shall "coordinate development and use of the water resources of the State so as to effect full utilization, conservation and protection of its water resources." The Water Resources Board in another section of the Act (Title 89-132.1) was charged with the preparation of "a continuing comprehensive inventory of the water resources of the State" and of "a comprehensive co-ordinated, multiple-use water resources plan."

OBJECTIVES AND SCOPE

The general objectives of the plan are clearly defined by the State policy statement quoted above and by the description of the plan in the law—"the state water plan shall set out a progressive program for the conservation, development, and utilization of the State's water resources, propose the most effective means by which these water resources may be applied for the benefit of the people, with due consideration of alternative uses and combinations of uses."

The state water and related land resources plan will be developed in four phases that form a rational and logical framework which clearly defines the scope of the plan. These include:

(1) An inventory phase which will result in accumulation of detailed knowledge of the resource and present management and use of it. Involved in this phase is computerizing of all raw data in a storage and retrieval system, to be known as the Montana Water Resources Data Center, and which will allow easy and rapid use of our water information in many ways including subsequent and current phases of the water plan.

(2) A water requirements and projection phase, the results of which, when balanced against the

inventory will allow the Board to estimate surpluses and deficiencies and to project and recommend developments for the future. Concentration of initial work in this phase will be on the early period up to 1980 for which relatively realistic projections can be made. However, the Board will pay some attention to projections for the years 2000 and 2020 in order to be in line with other planning now taking place in the West.

(3) A phase involving recommended developments to be accomplished between the present and 1980 and by the years 2000 and 2020. These recommended developments will be conditioned not only by the findings of the inventory and requirements phases of the state water plan but by the coordination of these findings with the work of the other planning agencies, especially the comprehensive statewide plan now being initiated by the State Planning and Economic Development Commission.

(4) An implementation phase, early segments of which may well be developed within the next two years with later segments developing as results accrue from the preceding three phases of the state water plan and other concurrent planning efforts.

Working within this scope and toward the objectives defined above the state water and related land resources plan is clearly a program that will stimulate knowledgeable thought and discussion which in turn will result in continuing refinement and modification. It should, therefore, be a dynamic plan flexible enough to accommodate changes as they develop and adjustments as circumstances change. As recommendations for development or other action are made, they should include enough detail to indicate clearly the objectives, required actions, alternatives, priority, and effects involved in the action so that the most urgent water and land resource problems are met and effectively answered first.

Among the early results of the plan should be included:

(1) Clear definition of the most urgent problems of water resources development.

(2) An accurate knowledge of the resource and its relative significance with regard to other resources of the State.

(3) Definition and adoption of a framework that allows development of both short and long-term recommendations for optional development and management of Montana's water resources.

(4) Coordination and reconciliation of the framework plan with other planning efforts by local, State, and Federal organizations.

(5) Coordination and inclusion of current developments, studies, and action within the plan.

(6) Production of summary progress reports to the public made as the plan develops. With regard to this last item, a series of reports on the inventory phase of the plan are now being written and, as they are completed, will be published. Presently proposed subjects for these reports include a directory and summary of the programs of all agencies working in the water resources field in Montana, an up-to-date bibliography of literature on Montana water resources, an inventory of existing reservoirs in Montana, a catalogue of stream-gaging stations and schematic diagrams of drainage systems, a summary of Montana water laws, a review of economic aspects of water resource development, patterns of management and administration of water resources in Montana, an inventory of potential reservoir sites, and inventories of surface water, ground water, water use, a hydrologic basin map atlas, and related land resources. Comparable reportage is planned on water needs as studies develop.

BASIC ASSUMPTIONS

In formulating a varied and broad program such as the state water and related land resources plan, certain basic assumptions and constraints must be assumed.

The Montana Water Resources Board has tentatively selected a set of assumptions largely based on national or international trends and conditions over which the State has little or no control but which could have appreciable effect upon basic decisions and recommendations arrived at by the plan. These assumptions include:

(1) There will be no **major wars or depressions** which will have extreme effects on long run economic development.

(2) The Federal Government will follow policies designed to stimulate **economic growth** in the State.

(3) Whenever possible water development in Montana will be for **multiple purposes.**

(4) **Water pollution and pollution control** will not restrain Montana's economic development.

(5) **Water availability** will not be a restraint to economic growth. In this respect it is recognized

that at present approximately one-sixth of total estimated run-off originating in the State is consumptively used, that one-third is used and returned to the streams, and that all of the water originating in the State is subject to at least one cycle of use within the State. Water use in excess of this amount is assumed to come from regional transfer or other sources.

(6) Essential **fish and wildlife** requirements will be met.

(7) **Population projections** relevant to the State water plan will be developed as a function of the economy.

(8) **Unemployment** of the civilian labor force will be four percent at national level but probably somewhat higher at the State level.

(9) Conventional **agriculture** will supply at least the same share of **requirements** in the future that it has in the past.

(10) **Irrigation efficiency** will remain basically as in the past.

(11) **Power demands** of the future will be met.

These assumptions agree generally with those made by planners in other states and those of the regional planners.

Certain other assumptions or "bias" resulting from conditions unique to the State are also tentatively considered. Among these might be mentioned the following:

(1) That the Board can best accomplish the planning mission by concentrating on development plans for the early future, i.e., between now and 1980, leaving much of the longer range developmental planning for later.

(2) That, in a State where flood flows make up more than fifty percent of total stream run-off, modulation of flow and low-flow augmentation with attendant necessary storage projects is the primary consideration for the optimum use of the greatest quantity of water for all users including recreation, fish and wildlife, and quality control. Therefore, first planning efforts should be direct to location, definition, and coordination of storage and basin transfer projects.

(3) Under the conditions mentioned above plus the fact that the greatest supply of potentially usable ground water is in alluvial basins closely associated with, and frequently hydraulically connected to the principal streams, a prime future use of ground water will be in conjunction with surface water to modulate and augment flows, especially during drouth periods. This is not to underrate the desirability of directly using ground water as a prime source for certain industrial operations, municipal supplies and domestic and stock use.

(4) Existing water rights and water law will be recognized as constraints in development of the plan.

STUDY PROCEDURE

As is required by the enabling legislation, the staff of the Montana Water Resources Board has organized and will conduct the water plan. The first year of operation was consumed in acquiring staff, inventorying existing data, formulating the framework, and participating in other planning efforts, primarily those of the MBIAC (Missouri Basin Interagency Committee) and the PNWRBC (Pacific Northwest River Basin Commission). During this second year of operation, these activities have been continued, a procedure for reporting on the work has been set in motion, the plan framework has been adopted, appropriate meetings and hearings to further inform the public have been planned or scheduled, and some progress has been made on phase two of the framework, that is, determining future water needs.

At present it is planned that the inventory phase will be almost completed this year and fully completed by the end of next year, at which time phase 2, water requirements, will also be essentially complete. The succeeding two years will be occupied with phase 3, formulating recommended developments (beyond current developments), probably on a project-by-project basis with most emphasis placed on the period between now and 1980 but with projections as may be desirable or required to at least the year 2020. Thus, by 1972 the Board will be ready to concentrate on phase 4, implementation, which will, of course, have been initiated with the acceptance of projects currently accepted and recommended by the plan during the next four years, 1968 to 1972.

Many agencies, local, state and federal, will assist the Water Resources Board in many aspects. Cooperating directly with the Board and supporting it with needed research is the University System, primarily the Joint University Water Resources Research Center at Bozeman, the University of Montana at Missoula, Montana State University at Bozeman, and Montana College of Mineral Science and Technology (including the Montana Bureau of Mines and

Geology) at Butte. Among other state agencies possessing records, information, and expertise in the water resources field are the following:

Fish and Game Department
Department of Health
Highway Department
Department of Lands and Investment
Legislative Council
Montana State Library
Oil and Gas Conservation Commission
Department of Planning and Economic Development
State Soil Conservation Committee

Federal Agencies include:

Department of Agriculture
- Soil Conservation Service
- Agricultural Research Service
- Economic Research Service
- Forest Service

Department of Commerce
- U. S. Weather Bureau
- Housing and Urban Development
- Office of Business Economics
- U. S. Bureau of the Census

Department of Defense
- U. S. Corps of Engineers

Department of Interior
- U. S. Bureau of Land Management
- U. S. Bureau of Reclamation
- U. S. Geological Survey
- Federal Water Pollution Control Administration
- Bureau of Indian Affairs
- Fish and Wildlife Service
- Water Resources Council

All of the planning work has been supported by State funds appropriated by the 1967 Legislature and by grants from the Water Resources Council under Title III of P. L. 89-80.

COORDINATION WITH OTHER PLANS

Comprehensive water resources plans which involve Montana resource development in more or less degree are being conducted by the Missouri Basin Interagency Committee, the Pacific Northwest River Basins Commission, Columbia-North Pacific Region Comprehensive Framework Study, and by neighboring states including Idaho, Washington, Oregon, Wyoming, North Dakota, and South Dakota.

Montana is also embarking upon a State-wide Comprehensive Plan for overall development under the leadership of the Department of Planning and Economic Development, a plan with which the State Water Plan should be harmoniously coordinated. Further, water resources development and planning in neighboring Canadian provinces may also directly or indirectly affect Montana planning. With these facts in mind, every effort is being and will be made to coordinate the water resources planning effort with the efforts of these entities, at least as long as effects deleterious to the prosperity of Montana and her citizens do not occur.

The Montana Water Resources Board staff has diligently observed and actively participated in, within the limits of their time and budget, the planning activities of MBIAC and PNWRBC, both of which are framework or "Type I" studies. Staff personnel are active members of committees and work groups of both organizations. A considerable proportion of the Board's planning effort has been and will continue to be expended in this work. Considerable return has resulted and is expected to result from this activity. By this participation, not only do Montanans keep aware of the overall development of these plans but they are able, either alone or in concert with representatives of other States, to formulate or at least influence studies and decisions that might otherwise ignore or omit consideration of various unique aspects and interests of Montana and other states. Further, this on-the-spot knowledge of the regional plans allows for much freer interchange of knowledge and information, for better understanding of points of disagreement, and for easier and more efficient coordination of the State and regional plans.

Through the efforts chiefly of the Governor's Office and the Water Resources Board, relationships with neighboring states are excellent and frequent exchange of planning information and operations are the rule. Many members of the planning staffs of the other states serve on the same work groups of the regional planning organizations and thus much mutual understanding and appreciation of planning objectives and problems exist. Under these conditions, as the various State plans develop, reasonable coordination and agreement should also result.

Presently, relationships between Montana and Canada in regard to water problems are regulated

amicably by two existing treaties, the Columbia River Water Treaty, adopted about ten years ago, and the Waterways Treaty (St. Mary and Milk Rivers) adopted in 1909. The Montana Water Resources Board will develop the State Plan in accordance with these treaties unless and until other agreements are consummated with Canada and the provinces of Alberta, Saskatchewan, and British Columbia. Presently effort is being made to find what planning and development activities are taking place in Canada.